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Geographic information system (GIS) approach for sustainable land resources development of watershed

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Abstract
A study was taken up in 'Yacharam' watershed of Ibrahimpatnam block of Ranga Reddy district, Andhra Pradesh ($17^{O}00^{/}$ to $17^{O}05^{/}$ N latitudes and $78^{O}35^{/}$ to $78^{O}45^{/}$ E longitudes) to map different basic natural resources of watershed viz., land use/land cover, hydro-geomorphology, soil and topography from remote sensing (IRS-IB, LISS-II) as well as conventional data sources and analysis of these maps through geographic information system (GIS). After mapping all the basic natural resources, composite land development unit map was prepared through GIS and action plan for alternate sustainable land development systems like agro-forestry, agro-horticulture, intercropping, intensive agriculture, silvipasture, horticulture, salt-resistant crops etc. were suggested in different parts of the watershed.

INTRODUCTION

Watershed characterization requires generation and gathering of precise information on a number of parameters of both static and dynamic in nature comprising of geology, geomorphology, hydrology, soils, land use/ land cover, soil erosion, climate etc. Sustainability has become the dominant issue in the management of environmental resources today and it is in this context that natural resources inventorying and evaluation have assumed greater significance in the realm of land use planning and management (Saxena *et. al*., 2000). Watershed characterization and management aims at the optimum utilization of land and water resources on sustainable basis which has been accepted as the most rational approach in preventing deterioration of ecosystem. Survey techniques and methods adopted in integrated survey of natural resources are sometime critical in making information available to the planners on time. With the introduction of remote sensing both from aerial and space platforms, a better means of data acquision system is now available which provides an accurate, reliable and updated data base on land and water resources.

The analysis of integrated data and their spatial distribution can effectively be done using geographic information system (GIS) because of its capacity to deign and organize an error free digital data base of natural resources in the form of spatial layers. Several studies have already been conducted in India (Dutta *et al*., 1997, Khan, 1997 & Ashok Kumar, 1999) for integrated watershed management using remote sensing and GIS approach. In this paper the remote sensing and conventional data sources were used for mapping of basic natural resources and site specific action plan for alternated land resources development was suggested in different parts of watershed using remote sensing and GIS techniques.

MATEREALS AND METHODS

The IRS-IB, LISS II satellite data in conjunction with conventional data sources (Survey of India toposheets, census report, meteorological observatory, soil profile information, agricultural research station, block/district agricultural office etc.) were used to prepare thematic maps of different natural resources of watershed. The thematic maps on 1: 50, 000 scale, prepared by A. P. state remote sensing centre in collaboration with National Remote Sensing Agency (NRSA) were also used for generation of thematic coverage's of major natural resources through geographic information system. The GIS coverage's of basic natural resource like existing land use/land cover, hydro-geomorphology, soil, and slope were prepared using ARC/INFO - 7.30 software for developing composite land development unit map. On the basis of integrated information in composite land development map, action plan for sustainable land resources was developed through GIS and the stepwise GIS methodologies are given in flow chart 1. The area of different classes were estimated in all the thematic maps using 'STATISTICS' command in 'ARC' module of ARC/INFO package.

Software used

(i) Workstation based (IBM AIX 3.2) ARC/INFO-7.03 GIS software developed by ESRI, USA

(ii) Workstation based ERDAS-IMAGINE 8.3 developed by ERDAS, USA in SGI, IRIS 4.0 operating platform.

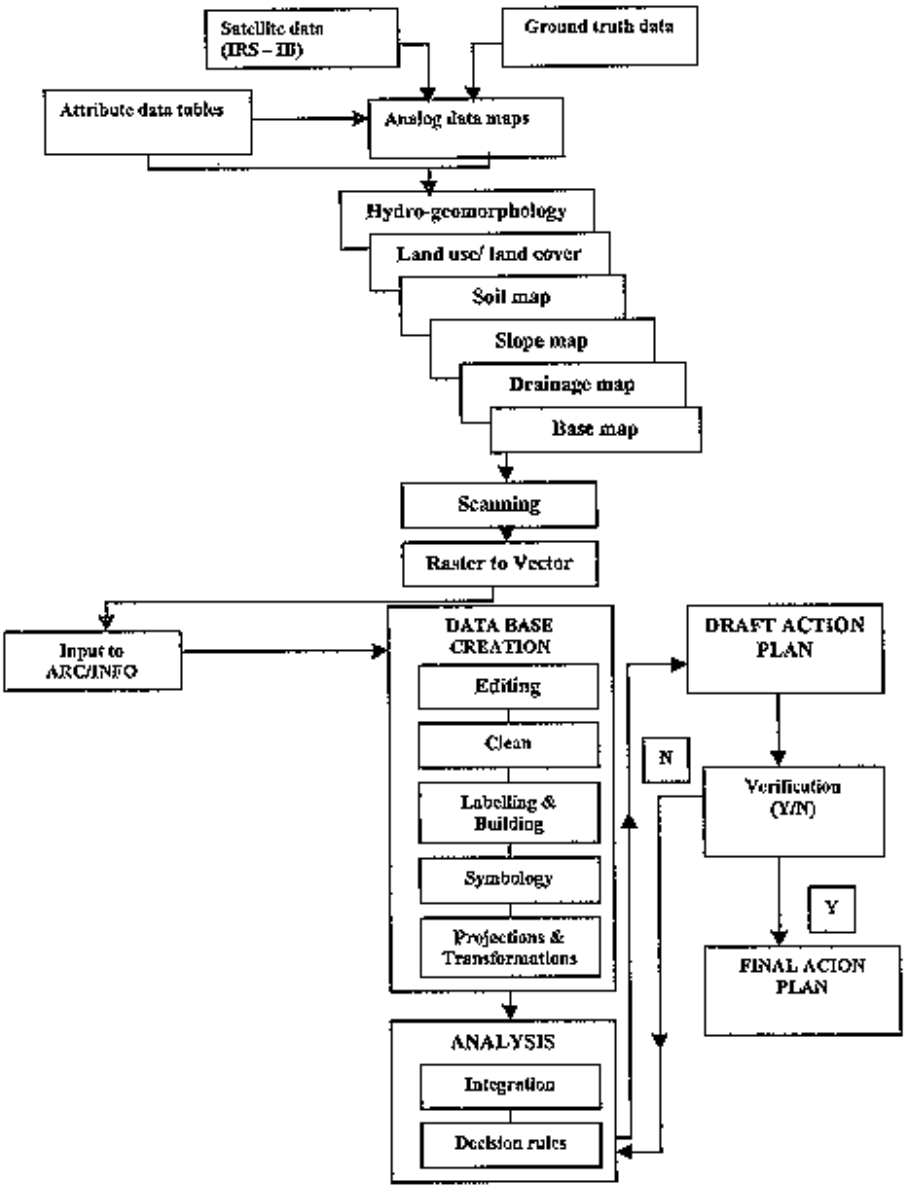
STUDY AREA

The study area was selected in ‘Yacharam’ watershed of Ibrahimpatnam block of Rangareddy district, Andhra Pradesh (17000/ to 17005/ N latitudes and 78035/ to 78045/ E longitudes) for sustainable land resources development through remote sensing and GIS. The total area of the watershed was approximately 13,000 ha. The climate of the study area was characterized by semiarid type with mean monthly maximum temperature 39.46 OC in the month of May and mean monthly minimum temperature of 28.14 OC in the month of December. Geomorphology of the watershed area was mainly a pediplains with hills and intruded with dolerite dykes. It had gently undulating topography. The drainage pattern of the region was dendritic to subdendritic.

OBJECTIVES

(a) Integration of basic natural resources information of watershed (remote sensing as well as conventional data sources) through geographic information system (GIS) and preparation of composite land development unit map.

(b) Development of action plan on the basis of composite land development unit map and decision rules for site specific sustainable land resources development



Flowchart 1. Flow chart of methodologies for generating action plan on land resources development of watershed.

RESULTS AND DISCUSSION

Hydro-geomorphology

Hydro-geomorphological feature of any region determines the type of soils exit, their water holding capacity and prospects of ground water availability in that zone. The hy-

dro-geomorphological features were mapped from IRS- IB satellite imagery with limited ground check and converted into GIS coverages to analyse and area estimation. The main hydro-geomorphological features were found to exist residual hills (closepet granite), residual hills (peninsular granites), valley fill, rocky pediment, (closepet granites), rocky pediments (peninsular granites), shallow weathered pediplains, tor/tor complex (peninsular granites), moderately weathered pediplains, tor/tor complex (closepet granite) etc. The sum area of each group of hydro-geomorphological features were estimated using 'ARC' module of ARC/INFO package and detailed geomorphological features with the area are given in table 1.

Table 1. Geomorphological features, physiography and structures of 'Yacharam' watershed.

Geomorphic unit/ Land form	Lithsostratography	Structure	Area (ha)	Description
Shallow weathered pediplain	Peninsular Granite and Gneisses	Fracture/Lineament	9626.7	Flat and smooth surface of weathered pediplain with 0-5 mts. Over burden weathered materials.
Tor/tor complex	Closepet granite	Joints/fractures	120.1	Group of spheroidally weathered boulders with isolated rocks
Rocky pediments	Closepet granite	Fracture/Lineament	192.4	Gently sloping smooth surface of erosional bedrock between hill and plain with veneer of detritus
Residual Hills	Closepet granite	Fracture/Lineament	869.0	Group of massive hills occupying considerably small area
Moderately weathered pediplain	Peninsular Granites And Gneisses	Fracture/Lineaments	830.7	Flat and smooth surface of weathered pediplain with 5-5 mts. weathering.
Rocky pediment	Peninsular Granites And Gneisses	Fracture/Lineaments	261.4	Gently sloping smooth surface of erosional bed rock between hill and plain with veneer of detruidus.
Tor/.tor complex	Peninsular Granites And Gneisses	Joints/Fracture/Lineaments	106.5	Group of spheroidally weathered Boulders with isolated rock out crops
Residual hills	Peninsular Granites And Gneisses	Fracture/Lineaments	238.9	Group of massive hills occupying considerably small area
Valley fill	Constitutes cobbles, pebbles, gravel, sand and silt	Fracture/Lineaments	943.8	The unconsolidated sediment deposited by stream / river normally in a narrow fluvial valley

Soil

A good understanding of the soils with reference to their nature and distribution is essential to formulate any land resources development. Among agricultural soils, suitability for crop production varies from soil to soil because their moisture and nutrient holding ca-

pacity varies. The area covering different soil series along with taxonomic classification for the watershed area was estimated using ARC/INFO package which are given in table 2, which reveals that watershed area is dominated by Ibrahimpatan Chintapatla soil series followed by Ibrahimpatan/Nanchal and Nandiwanapart/Malkeshguda.

Table 2. Soil series and taxonomic classification of the watershed area.

Soil series/association	Physiography	Area (ha)	Description	Taxonomic classification
1. Aghapalli/Maal	Residual Hills	124.4	Shallow to moderately deep, coarse textured, excessively drained, very severely eroded soils on steep slopes	Loamy skeletal/ mixed, Lithic/Typic Ustorthents
2. Rangapur/Gaurelli	Foot slopes	952.5	Moderately deep, coarse to medium textured, well drained, severely eroded soils on strong slopes	Loamy skeletal/ mixed, Typic Ustroepts /Haplustalfs
3. Chauderpalli /Chided	Tor complex	1371.6	Shallow, coarse to medium textured, excessively drained, very severely eroded soils on moderate slopes	Loamy skeletal/coarse mixed, Typic Ustorthents
4. Rangapur/ Ibrahimpartnam	Rocky pediments	707.7	Moderately deep, coarse to medium textured, well drained, severely eroded soils on moderate slopes	Loamy skeletal/ mixed, Typic Ustroepts /Haplustalfs
5. Ibrahimpatnam/ Chintapatla	Upper pediments summits	3820.4	Moderately deep, medium textured, well drained, severely eroded soils on moderate slopes	Loamy skeletal/fine loamy, mixed Typic Rhodustalfs /Haplustalfs
6. Ibrahimpatan /Manchal	Upper pediments side slopes	2499.4	Deep to very deep, medium to fine textured, well drained, severely eroded soils on moderate slopes	Fine loamy/loamy skeletal, mixed Typic Rhodustalfs
7. Lower pediplains	Khanpur/Manchal	391.6	Deep to medium textured, well drained, slightly eroded soils on gentle slopes	Fine loamy/loamy skeletal, mixed Typic Ustorpets/Rhodustalfs
8. Narrow valleys	Nandiwanaparti/ Malkeshguda	1425.5	Deep coarse to medium textured, poorly drained soils on nearlylevel slopes	Coarse to fine loamy, mixed Typic Ustorpepts
9. Broad valleys	Nomul/ Malkeshguda	674.1	Deep to very deep, medium to fine textured, imperfectly drained soils on nearly level slopes	Fine loamy, mixed Fluventic Typic Ustorpepts
10. Dykes	Gungal	112.1	Shallow coarse, excessively drained very severely eroded soils on strong slopes	Loamy skeletal, mixed Typic Ustorthents

Slope

Slope is the most important terrain features from land utilization point of view. This parameter in watershed is vital for land irrigability, land capability classification by determining the soil loss due to water erosion. The slope map, prepared from Survey of India toposheet on 1: 50,000 scale was used to generate action plan. The area of different categories of slopes were estimated using 'ARC' module of ARC/INFO package and are given in table 3.

Land use and land cover

Information on existing land use/ land cover and pattern of their spatial distribution forms the basis for any further developmental planning. The current land use/ land cover was

mapped and assessed for its suitability in respect of land potentials / limitations for site specific alternate land use system. The land use /land cover map was prepared by A,P.Remote Sensing Centre, Hydearabad using IRS 1A/B data was used for preparing GIS coverage's. The area of each category was estimated using ARC/INFO package and are given in table 4. The GIS land use/land coverage or spatial distribution of existing land use/land cover is given in figure 1.

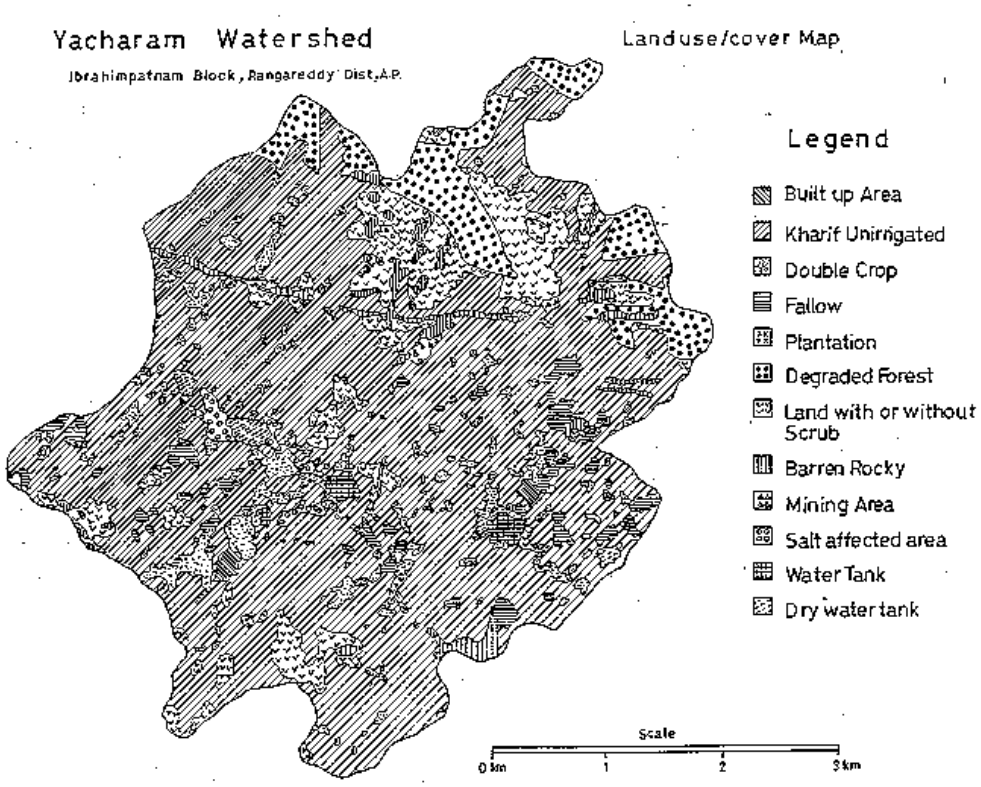


Figure 1. GIS land use/land coverage or spatial distribution of existing land use/land cover.

Table 3. Area covering different categories of slope in 'Yacharam' water-shed area.

Sl. No.	Class	% of slope	Area(ha)
1.	Nearly level	0 – 1 %	2137.1
2.	Very gentle	1 – 3 %	7966.6
3.	Gentle	3 – 5%	1531.6
4.	Moderate	5 – 10 %	942.2
5.	Moderate steep	10 – 15 %	377.8
6.	Steep	15 – 35 %	199.9

Table 4. Area covering different existing land / land cover in 'Yacharam' watershed'.

Sl. No.	Class name	Area (ha)
1.	Built-up land	44.7
2.	Kharif unirrigated	8991.9
3.	Kharif irrigated	730.0
4.	Fallow	387.7
5.	Plantation	9.1
6.	Degraded/under utilized forest	985.7
7.	Land with/without scrub	1362.0
8.	Barren rock/stony waste/sheer rock area	43.7
9.	Mining area	88.3
10.	Salt affected area	107.3
11.	Dry water tank	185.6
12.	Water tank	94.0

Table 5. Area of the proposed alternate land use system in different parts.

SL NO.	ALTERNATIVE LAND USE	AREA (ha)
1	Gap plantation	2529.4
2	Horticulture	6562.4
3	Conversion to double cropping	1408.8
4	Agro forestry	438.9
5	Horti-pasture	218.7
6	Agro-horticulture	496.1
7	Silvipasture	194.3
8	Intercropping system	193.1
9	Existing water bodies	344.2
10	Stablisation of mining dumps	73.6
11	Existing double cropping	389.8
12	Salt resistant crop	106.1
13	Existing plantation	6.2
14	Built-up area	44.0

Action plan for alternate land use development

To plan an alternate land use pattern in different parts of the watershed, available basic natural resources (existing land use/land cover, hydro-geomorphology, soil and topography) of the watershed were integrated and composite land developmental development unit map was prepared. From existing land use / land cover map, it is revealed that water source for double cropping was limited. Therefore, tendency of the farmers to increase the long duration *rabi* crops is to be discouraged and the alternate land resources like agro-forestry, agro-horticulture or silvipasture are to be adopted in land presently under scrub or degraded/under utilized forest. Suitable contingent crop plans like 'cover crop', 'catch crop' should be practiced to combat aberrant weather situations, when main crops fails to produce. In the valley fills where high water retention capacity exists, double

cropping with short duration pulses and oilseeds should be practiced under proper crop and water management strategies. In the present study, based on land capability, duration of south west monsoon period, socio-economic conditions and diversified need of the farmers, a suitable crop plans and land use pattern have been prepared in different of the watershed. Presently the vast area were under un-irrigated *kharif* paddy with very low productivity. The different drought resistant horticultural crops were recommended to obtain more income by the farming community by discouraging un-irrigated kharif which grows in marginal land and under aberrant weather situations. Attempts were also made for generating action plan for stabilizing mining area, wasteland reclamation etc. The alternate land use pattern are depicted in table 5 and GIS coverage or spatial distribution of newly recommended land use/land cover practices are given in figure 2.

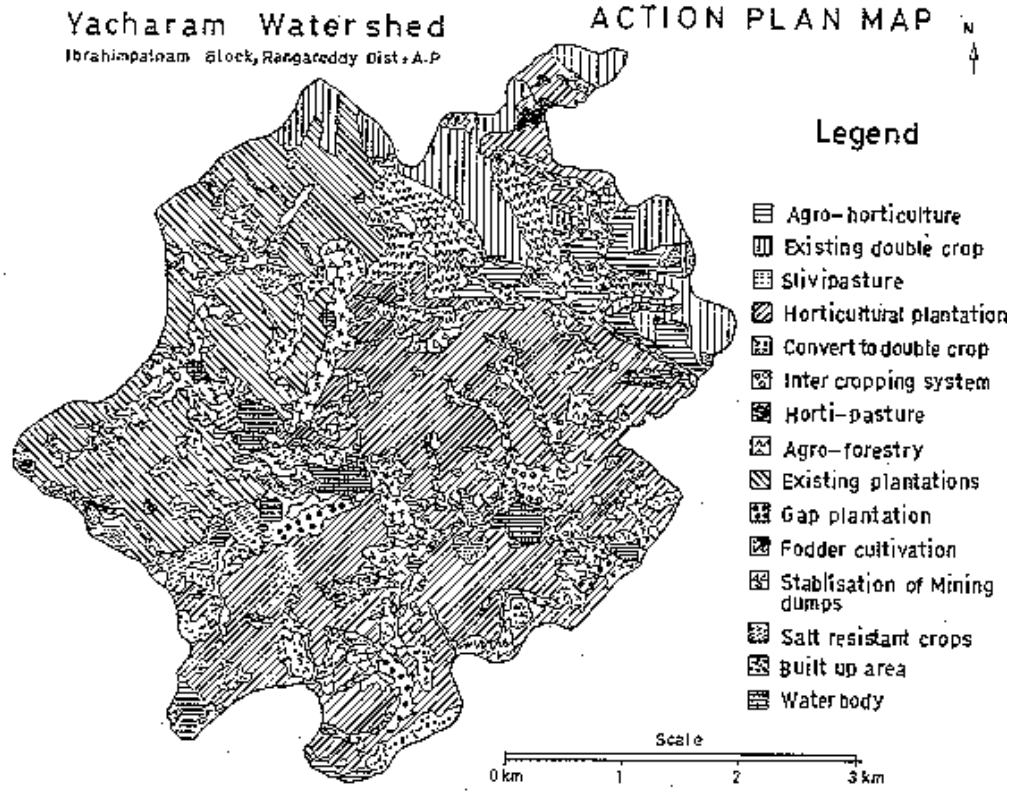


Figure 2. GIS coverage or spatial distribution of newly recommended land use/land cover practices.

CONCLUSION

The study revealed the usefulness of remote sensing technology for providing up-to-date, reliable and accurate information on different natural resources like existing land us/land cover, hydro-geomorphology, soil and topographical features of watershed etc. The GIS technique is helpful to integrate these all information into a composite land unit development map for generating action plan.

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